REMARKS/ARGUMENTS

In the Office action dated March 15, 2005, the Examiner rejected claims 1-22, all of the claims in the Application. Claims 1, 2, 7-9, and 14-17 stand rejected under 35 U.S. C. § 102(b) as being anticipated by Chun *et al.*, *In-Situ Surface Preparation of InP-Based Semiconductors Prior to Direct UVCVD Silicon Nitride Deposition for Passivation Purposes*, pages 412-415, (1996). Claims 3-5, 10, 11, 13 and 18-21 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Chun *et al.*

In the Specification, no changes

In the Claims, no changes.

The Invention

The invention is a method of forming a high quality silicon nitride layer at low temperature in an integrated circuit. The method of the invention employs the use of nitrogen radicals to convert silicon to a silicon nitride. The method of the invention may also form a thin nitride layer on an already-grown silicon oxide layer by displacing the oxygen at the top surface and converting at least a portion of silicon oxide to silicon nitride. The method of the invention does not use a plasma discharge, which may cause substantial damage to the silicon wafer. The method of the invention generates large quantities of nitrogen radicals on or near the surface of a silicon layer, or silicon oxide layer, which is to be converted to silicon nitride. The radicals are generated by the photolysis, or photo-dissociation, of NH_3. The light source used is a Xe_2 excimer lamp which emits at a wavelength of 172 nm, or 7.21eV in energy. The direct illumination of the wafer surface at such an energy level may generate photoelectrons and a charged surface that may participate in the nitridation process. The work function of silicon is

less than 5eV, so electrons can have over 2.2eV of kinetic energy. Electron attachment of the low energy electrons may generate negatively charged species, such as NH_2^-, that are quite stable. Adsorbed molecules on the surface of the substrate may also play a role in the nitride layer growth. The growth of the film may be assisted by a field across the growing dielectric layer where a positively charged interface attracts negative ions.

The Applied Art

Chun *et al.* describe formation of a nitride layer on a III-V semiconductor, which requires introduction of a silicon-containing gas into a deposition chamber, *,e.g.* SiH_4, as shown in Fig. 2. An ultra-violet light source is provided in the form of a mercury vapor lamp, which well known to emit light over a broad range, and while it is claimed to emit at 185 nm (Fig. 2), such a claim is clearly erroneous. While XeF_2 is provided in one aspect of the method, there is no mention of a xenon excimer lamp.

The Claims

Claim 1 specifically recites the characteristics of the light used in the method of the invention, specifically recites the gases which may be used, and specifically recite that the silicon nitride layer formed by the method of the invention is less than 5 nm in thickness and is formed from the silicon wafer and the dissociated nitrogen. The Examiner has applied Chun *et al.* as a 102(b) reference. This is an inappropriate reference because Chun *et al.* do not form a silicon nitride layer using silicon from the wafer, nor do Chun *et al.* dissociate a nitrogen-containing gas with photo energy from a xenon excimer lamp operating at a wavelength of 172 nm. Applicant has provided, as Attachments 1 and 2 hereto, an Osram products brochure which describes a xenon excimer lamp system, and a Technical Bulletin which describes mercury vapor

lamps, respectively. One of ordinary skill in the art will readily recognize the vast difference between the light characteristics emitted by these two radically different lamps. They are clearly not interchangeable for their intended purposes as used by Chun *et al.* and by Applicant. The mercury vapor lamp, as used by Chun *et al.*, operates over a wide spectra, with only a very small portion of its light being in the sub-258 nm range, and therefore, does not have anywhere near sufficient energy to dissociate the nitrogen-containing gas used by applicant, which dissociation requires the much higher energy of the xenon excimer lamp. The xenon excimer lamp used by Applicant has almost all of its power output at 172 nm, where the light is operable to break NH_3 into nitrogen radicals and hydrogen. Nowhere in Chun *et al.* is a claim made that the mercury vapor lamp dissociates the NH_3 gas. The NH_3 gas is described as "activated" by Chun *et al.* (p. 413, col. 1), however, "activated" is not "dissociated." In the case of XeF_2, the UV is sufficient to dissociate the molecule into its atomic components, however, this does not work for NH_3. Applicant, contrary to the Examiner's assertion, provides evidence that the 172 nm wavelength and 7.21eV energy produced by the xenon excimer is required to dissociate NH_3, Specification, page 3, line 19 through page 4, line 4. Thus, the "dissociating" element of the claim is neither taught nor suggested by Chun *et al.*, and the claim is allowable for that reason.

Further, Chun *et al.* provide a separate source of silicon in the form of SiH_4, and cannot possible form silicon nitride from the silicon in a wafer, because the wafer used by Chun *et al.* does not have any exposed silicon to react with the dissociated nitrogen. Although mention is made, on page 412 of Chun *et al.*, that there has been a previous report of forming silicon nitride on a silicon substrate, the reference is to an earlier work (reference 5) which has not been provided. The portion applied by the Examiner states that the UVCVD chamber was used in the

previous work, which chamber provides SiH_4 as the silicon source, not a silicon wafer. Thus, the forming a silicon nitride layer from silicon wafer element of the claim is neither taught nor suggested by Chun *et al.*, and the claim is allowable.

Claim 2 recites that the pressure in the chamber is between 5 mTorr and 200 mTorr. As explained in Applicant's Specification, the method of the invention includes forming a silicon nitride layer at low temperature and low pressure, which is different from the prior art, and which is certainly not anticipated by '148. Claim 2 is allowable over the applied art.

Claims 3-5, 7 and 8 are allowable with their allowable parent claim.

Claim 7 is allowable for the reasons set forth in connection with claim 1.

Claim 9 is allowable for the reasons set forth in connection with claims 1 and 2: there is no teaching nor suggestion in '148 that an excimer lamp be used to dissociate a nitrogen-containing gas into nitrogen which is used to form a layer of SiN on a silicon wafer, using silicon from the wafer, at a temperature of between about room temperature and 400°C, and at a pressure of less than 200 mTorr.

Claims 10, 11 and 13-15 are allowable with their allowable parent claim.

Claim 16 is allowable for the reasons set forth in connection with claims 1 and 9.

Claims 17-22 are allowable with their allowable parent claim.

In light of the foregoing amendment and remarks, the Examiner is respectfully requested to reconsider the rejections and objections state in the Office action, and pass the application to allowance. If the Examiner has any questions regarding the amendment or remarks, the Examiner is invited to contact the undersigned.

Provisional Request for Extension of time in Which to Respond

Should this response be deemed to be untimely, Applicants hereby request an extension of time under 37 C.F.R. § 1.136. The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any over-payment to Account No. 19-1457.

Respectfully submitted,

Date: 5/23/05

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Unique advantages of excimer lamp system

The compact XERADEX systems offer a multitude of advantages to the user:

- For the first time, a highly efficient VUV radiation source is available for different demanding industrial applications
- Its 40 percent efficiency eliminates the need for cooling of the lamp - the temperature of the radiator never exceeds 80°C (176° F) "cold radiation"; low temperature processing is possible
- The system of lamp and electronic control gear is compact and easy to handle
- Convenient, compact irradiation systems are possible, minimizing space in costly cleanroom environments
- Lamp starts instantly with no warm-up phase; the ignition is independent of the ambient temperature; no shutters are necessary
- No limitations on switching cycles; capable of instant restrike with no detriment to lamp life
- PLC control output
- Operation of the lamp in different environments is possible, such as in gaseous media and under vacuum conditions
- The lamp is environmentally friendly; it contains inert gases exclusively with no mercury used

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Excimer lamp system
Fields of application
Unique advantages

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Excimer lamp system

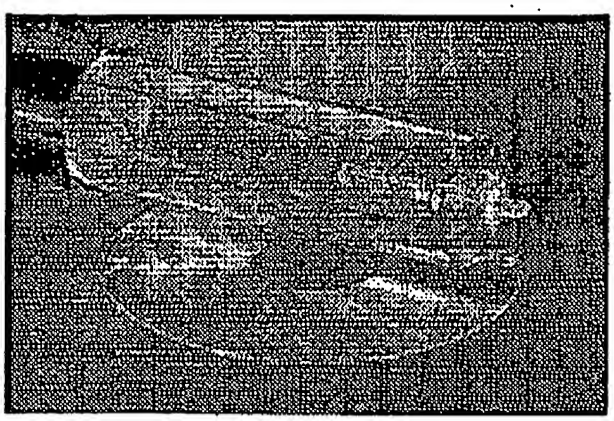
Highest efficiency for wafer cleaning, glass cleaning, **surface activation** and **ozone production.**

The revolutionary XERADEX xenon excimer lamp system from OSRAM opens up entirely new possibilities in process technology. Our patented pulsed mode of operation yields four times the radiation power of conventional excimer radiators: 40 percent of the input energy is converted into useable vacuum ultraviolet (VUV) radiation. Their high efficiency makes these systems ideal for very effective, flexible use in many demanding applications, such as surface treatment, ozone production, laquer frosting, water purification, and many more.

The unique operating principle leads to unbeatable efficiency - with no cooling required The XERADEX system has an outstanding 40 percent conversion efficiency (electrical to UV) compared to 10 percent in conventional sinusoidally driven systems. This tremendous advantage is due to our patented pulsed operation mode and to the innovative lamp design of XERADEX. When operated using the companion electronic control gear (ECG), the result is a compact system of remarkable performance. The quartz bulb functions as a dielectric barrier within a unique electrode system, which prevents the formation of an electric arc during the discharge phase. If xenon is the fill gas - as in the XERADEX lamps - and if a special pulsed voltage is applied across the electrodes, unstable xenon excimer molecules (Xe_2^*) are formed from the xenon atoms. These molecules dissociate by emitting VUV radiation at 172 nm. The XERADEX lamps emit incoherent VUV radiation.

The exceptional efficiency of these systems means no cooling of the lamp is required, as the temperature of the radiator never exceeds 80°C (175°F). This flexibility facilitates the integration of XERADEX systems into even the most sophisticated processes and advanced production equipment.

Please find an overview of the advantages **here.**



Fields of application

- **Surface activation and modification**
- **Ozone production**
- **Water cleaning and ultra-pure water preparation**
- **Evaluation of fluorescent substances**
- **Photochemical experiments**

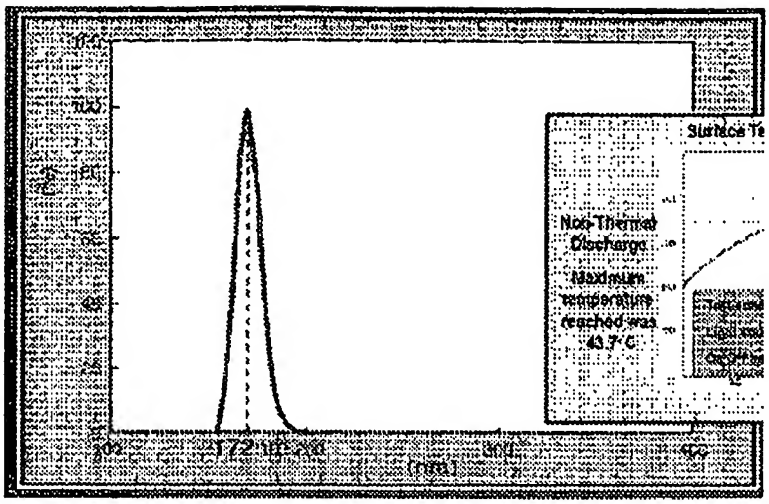


Figure 2. Spectral output of Xe excimer lamp.

Trojan Technical Bulletin #57

Mercury Arc lamps

The most common sources of UV are commercially available low and medium-pressure mercury arc lamps. A typical mercury arc lamp (Figure 1) consists of a hermetically sealed tube of UV-transmitting vitreous silica or quartz with electrodes at both ends. The tube is filled with a small amount of mercury and an inert gas, usually argon. The electrodes are usually composed of tungsten with a mixture of alkaline earth metals to aid arc formation within the lamp. A gas discharge is struck by applying a high voltage across the electrodes. UV light is emitted from the lamp when mercury vapor, excited by the discharge, returns to a lower energy state. Argon is present to aid lamp starting, extend electrode life, and reduce thermal losses. Argon does not contribute to the spectral output of the lamp.

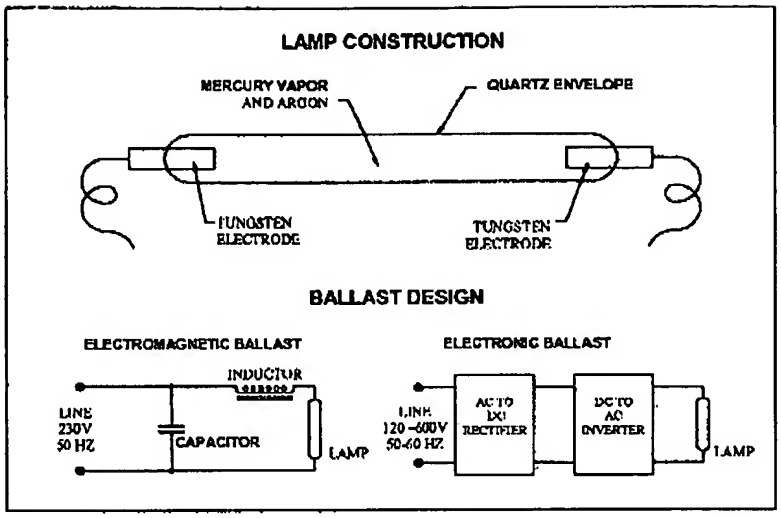


Figure 1: Mercury arc lamp construction and ballast design.

Due to the negative resistance electrical characteristics of gas discharges, stable operation of a mercury arc lamp requires ballast. When the lamp is operated using an AC supply, the ballast usually requires both inductive and capacitive components. Ballasts may be characterized as either electromagnetic or electronic (Figure 1). Electromagnetic ballasts typically consist of an inductor in series with the lamp and a power factor correction capacitor in parallel. Power is delivered to the lamp at the line frequency of 50 or 60 Hz. Electronic ballasts have an AC to DC rectifier followed by an inverter to convert the DC to high frequency AC in the kilohertz range. Electronic ballasts can be more compact, reduce system cost, have a greater electrical efficiency, and can operate at various power settings. As well, operation of the lamp at a higher AC frequency increases lamp output and e xtends lamp life.

Conventional Low Pressure Lamps

Vary in length from 35 to 163 cm with a diameter between 1.2 and 1.9 cm. A 1.5-meter lamp has 50 – 100mg free Hg. Lamps are designed to operate at optimal efficiency with a lamp wall temperature of 40°C and an UV output near 0.2 W/cm. Under these conditions, the mercury vapor pressure within the lamp is 0.9 Pascals and most of the mercury is in a liquid state. The construction, filling, and operation of a low-pressure lamp are selected to maximize the conversion of electrical energy to resonant UV radiation at 254nm and 185nm. Approximately, 85% of the light emitted from a standard low-pressure lamp is resonant UV radiation. Including ballast losses, conversion of electrical energy to UV light is approximately 35 to 40% efficient. A 147cm standard low-pressure lamp can be expected to produce 26.7 to 32W of UV at 254nm given an electrical input of 75-88 W.

Amalgam Lamps

These lamps are a modified version temperatures the arc power can be increased to 1.5W/cm resulting in a UV output of 0.5W/cm. Similar to conventional low-pressure lamps, amalgam lamps are optimized to produce resonant UV radiation at the 254nm wavelength. Including ballast losses, conversion of electrical energy to UV light is approximately 30-35% efficient.

Medium Pressure Mercury Arc Lamps

Vary in length from 25 to 70 cm and have a diameter near 2.2 cm. During lamp manufacture, a measured mass of mercury is introduced into the lamps (1.4 to 15 mg Hg/cm arc length). The lamps are designed to operate at a relatively high electrical arc power of 48 to 126 W/cm (Phillips, 1983). Accordingly, the lamp wall temperature is between 650 to 850°C and all of the mercury within the lamp is vaporized to a vapor pressure near 13 kPa. Due to the high plasma temperature within the medium pressure lamp, vaporized mercury exists in a number of excited states. Transition of the excited states to a lower energy level results in the release of light at various wavelengths. Accordingly, the UV spectral output of a medium pressure lamp consists of numerous peaks with a continuum of UV below 245nm. Ignoring radiation below 248.3nm, Phillips (1983) reports that a medium pressure lamp operating at an electrical arc power of 107 W/cm produces 9.38 W/cm of UVC and 8.19 W/cm of UVB. Thus at least 44% of the total radiation emitted by a medium

pressure lamp is UVB and UVC. Conversion of electrical energy to UVB and UVC is at least 16% efficient. Accordingly, a 25cm long medium pressure lamp can be designed to produce 450 W of UVB and UVC given an electrical input of 2.8 kW. While conventional low-pressure and amalgam lamps are more electrically efficient than medium pressure lamps, medium pressure lamps produce a greater UV output per lamp. Accordingly, amalgam and medium pressure UV systems can be expected to use fewer lamps, take up less space, and require less maintenance. As well, due to the reduced number of lamps, amalgam and medium pressure UV systems can cost effectively incorporate automatic cleaning systems to remove fouling that accumulates on lamp sleeves during water disinfection, thereby significantly reducing labor associated with lamp maintenance. Whether a low or medium pressure system, or a combination of the two, is appropriate for a particular application will depend on the requirements of each specific site.

Suggested Reading

Phillips, R. (1983). Sources and Applications of Ultraviolet Radiation. Academic Press Inc.

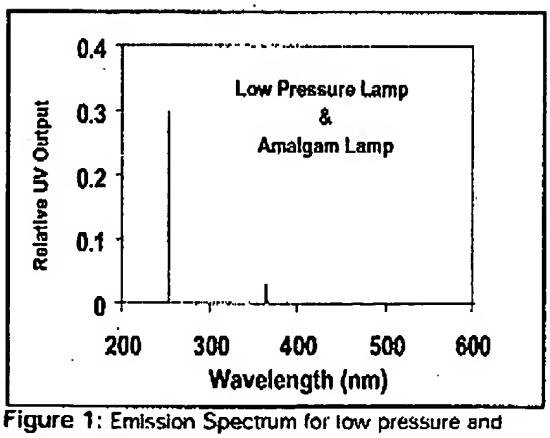


Figure 1: Emission Spectrum for low pressure and amalgam lamps.

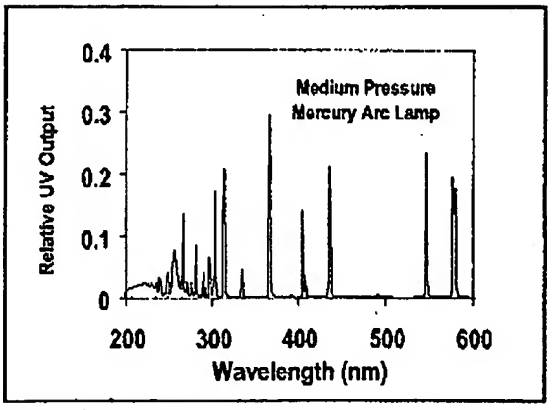


Figure 2: Spectral output for medium pressure lamp.

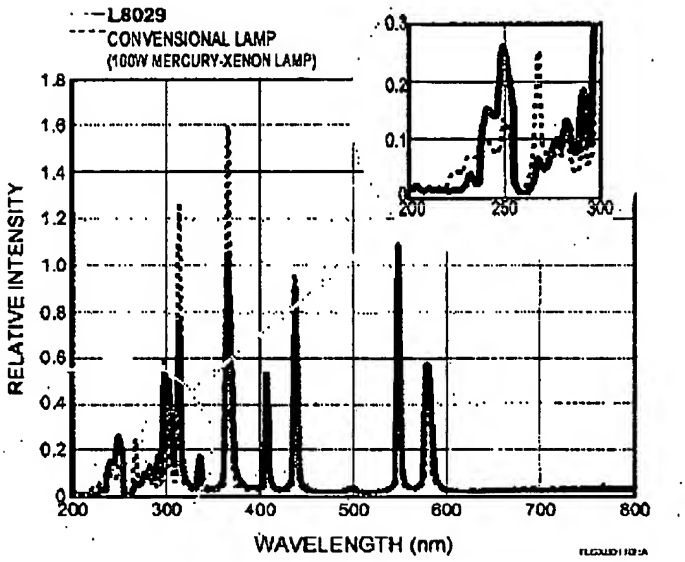


Figure 1. Hamamatsu L8029 High brightness, DUV enhanced 100W Mercury -Xenon lamp.

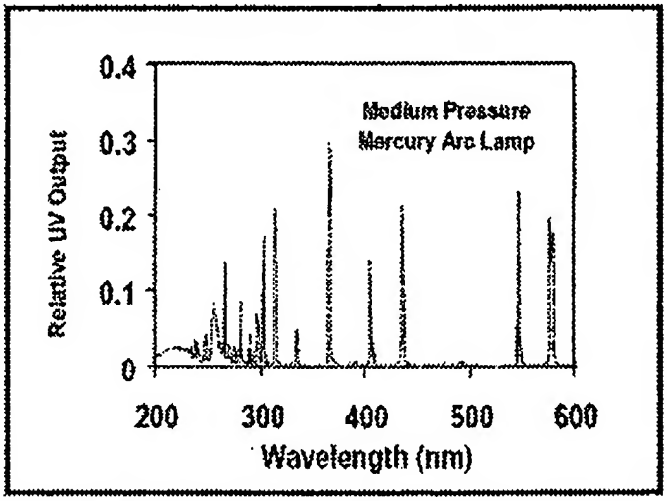


Figure 2: Spectral output for medium pressure lamp.